

Technical Memorandum

LOWER EAST FORK WASTEWATER TREATMENT PLANT IMPROVEMENTS CLERMONT COUNTY, OHIO

Subject: Phosphorus Removal Study

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This technical memorandum (TM) presents the results of process modeling to determine chemical and biological treatment phosphorus removal options at Lower East Fork (LEF) wastewater treatment plant (WWTP). The study was performed to comply with Ohio EPA's request for preparing options and associated costs for WWTP modifications to meet an effluent permit requirement of 1.0 mg/L of total phosphorus (TP). Cost estimates for each option are attached to this TM.

Background

The LEF WWTP consists of preliminary and secondary treatment facilities, along with filtration, post aeration, UV disinfection, and aerobic sludge digestion. The existing secondary treatment oxidation ditches and secondary clarifiers, filters, sludge digesters, and dewatering facilities were included a computer process model, based on the following summary and flow sheet schematics presented in the modeling discussion below.

- **Oxidation Ditches:** Two tanks, with a total volume of 6.2 million gallons (MG)
- **Final Clarifiers:** Four tanks of three different sizes, with total surface area of 28,000 square feet
- **Aerobic Digesters and Sludge Storage:** Two tanks, with a total volume of 2.4 MG

Performance and process control data for 2016 and 2017 provided by the County was organized into summer and winter data sets to develop corresponding seasonal models. A summary of the data organization follows.

During 2016 summer (June-October), the WWTP treated an average of 3.6 million gallons per day (range of 2.3 to 9.1 mgd). During 2016-2017 winter (November-April), the WWTP treated an average of 4.9 million gallons per day (range of 2.9 to 13.9 mgd). Per the effluent loading limitations of Ohio EPA's NPDES Permit 1PK00009MD, the permitted average design flow of the LEF WWTP is 9.0 mgd. Effluent produced in summer of 2016 and winter of 2016-2017 was within the permit limits for carbonaceous biochemical oxygen demand (CBOD), total suspended solids (TSS), and ammonia-nitrogen (NH₃-N).

In addition to regulated constituents, LEF staff has tracked total phosphorus (TP) as part of their plant-wide process control monitoring, which includes mixed liquor suspended solids (MLSS) concentration in the oxidation ditches. Permit and operating values for each of the important effluent and process control variables are summarized in the following list.

- **CBOD** permit level of 10 mg/L monthly maximum.
 - 2016 summer average of 2.3 mg/l and a range of 2.0 to 5.1 mg/L.
 - 2016-17 winter average of 2.1 mg/l and a range of 2.0 to 3.6 mg/L.
- **TSS** permit level of 12 mg/L monthly maximum.
 - 2016 summer average of 1.1 mg/L and a range of 1.0 to 2.0 mg/L.
 - 2016-17 winter average of 1.3 mg/l and a range of 1.0 to 2.7 mg/L.
- **NH3-N** permit level of 1.0 mg/L (summer) and 3.0 mg/L (winter) monthly maximum.
 - 2016 summer average of 0.28 mg/L and a range of 0.10 to 8.1 mg/L.
 - 2016-17 winter average of 0.11 mg/l and a range of 0.10 to 0.53 mg/L.
- **TP Concentrations:** 2016 summer average of 3.4 mg/L and a range of 2.5 to 4.4 mg/L; 2016-17 winter average of 2.2 mg/l and a range of 0.82 to 4.1 mg/L.
- **MLSS Concentrations** are tracked separately for each oxidation ditch.
 - **Ditch 1:** 2016 summer average of 2,108 mg/L and a range of 1,240 to 2,530 mg/L; 2016-17 winter average of 2,450 mg/l and a range of 1,970 to 3,000 mg/L.
 - **Ditch 2:** 2016 summer average of 2,047 mg/L and a range of 1,260 to 2,330 mg/L; 2016-17 winter average of 2,430 mg/l and a range of 1,920 to 3,040 mg/L.

An analysis of the LEF WWTP influent was also conducted, particularly with respect to the skewed proportion of CBOD and TSS loads the plant experiences. It was anticipated that LEF WWTP would have a more traditional domestic sewage concentration ratio (as compared to the MEF WWTP influent, which is specifically influenced by septage slug loads). However, the LEF influent concentrations are closer to the MEF data rather than conventional proportions (which CBOD is typically equal or exceeding TSS concentrations by 15-percent). The seasonal LEF WWTP influent summary follows.

- **Influent CBOD Concentrations:** 2016 summer average of 146 mg/L, with a range of 51 to 290 mg/L; 2016-2017 winter average of 135 mg/L, with a range of 57 to 264 mg/L
- **Influent TSS Concentrations:** 2016 summer average of 481 mg/L, with a range of 154 to 1,650 mg/L; 2016-2017 winter average of 503 mg/L, with a range of 94 to 4,020 mg/L

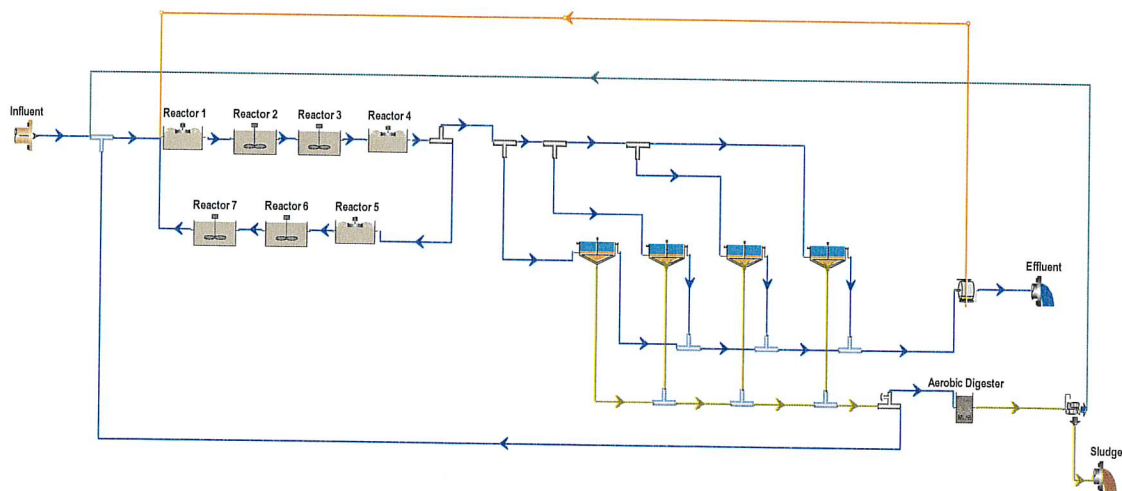
Conversations with County staff suggested this data skew may be related to industrial contributions in the service area. Consequently, the same revised parameters supplanting the process model default values in the MEF WWTP process model were also applied to those process models developed for LEF WWTP.

WWTP Process Models

The computer model developed for the LEF WWTP is based on the 2016-17 influent wastewater data and geometry of the existing process basins in use at the plant. The process model used with this data is a commercial program called BioWin. The first step of the modeling task was to set up seasonal simulations of the existing WWTP under current influent flows and concentrations and operating parameter. This step is commonly referred to as *calibration of the base models*.

Applicable summer and winter conditions were modeled with corresponding average flow and concentration parameters noted in the data summary above. Both oxidation ditches were simulated in operation during development of the base models, along with two of the four secondary clarifiers (one 120-ft clarifier and one 75-ft clarifier). Additional clarifiers were placed into service for increased flows and loads (up to the maximum day influent flow of 21.0 mgd, where all four of the clarifiers were placed online).

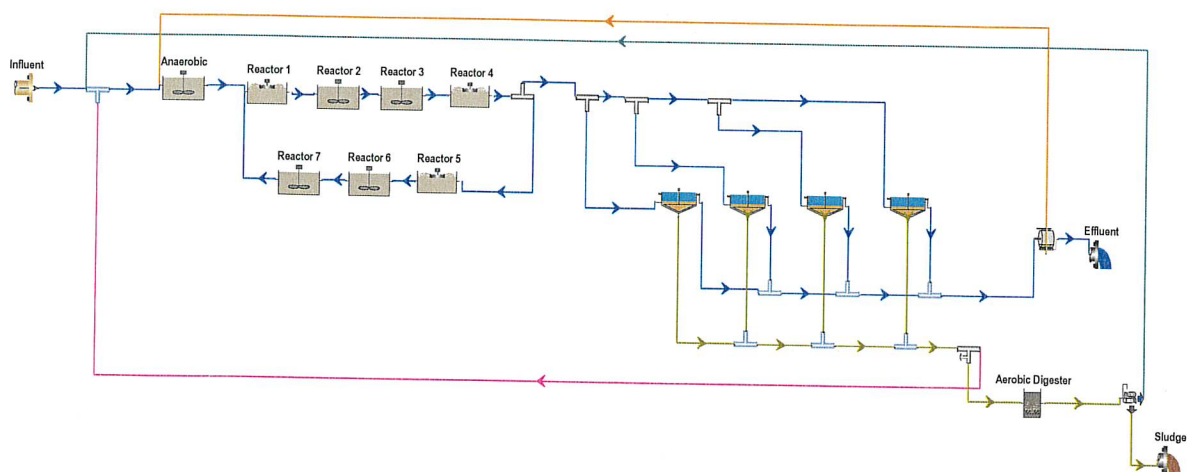
Configuration of the base model consolidated both oxidation ditches into a series of reactor icons, which simulated sections of each oxidation ditch apportioned by geometry and oxygen content characteristics. Reactor 1 and Reactors 4/5 house the two surface aerators in each ditch, and the other four portions of the ditch are shown as mixed reactors with declining dissolved oxygen content between aerators. Each of the four clarifiers were modeled individually, with clarifiers shown in the model diagram below from left to right, Clarifier 4 (120 ft diameter), Clarifier 3 (100 ft diameter), and Clarifiers 2 and 1 (each 75 ft diameter).



For both winter and summer conditions, effluent parameter concentrations projected by the initial calibration type run of the BioWin models were slightly above the data ranges recorded by WWTP staff during the 2016-17 operating period. Much like the MEF WWTP influent data, the elevated TP levels predicted in the LEF models are the result of the skew in CBOD and TSS influent loads. Again paralleling development of the MEF WWTP models, B&N employed the assistance of EnviroSim staff (developers of the BioWin program) to adjust volatile suspended solids (VSS) and CBOD fractions to reflect the data skew. Those models demonstrate TP effluent concentrations for both summer and winter conditions matching well the actual recorded WWTP operational parameters.

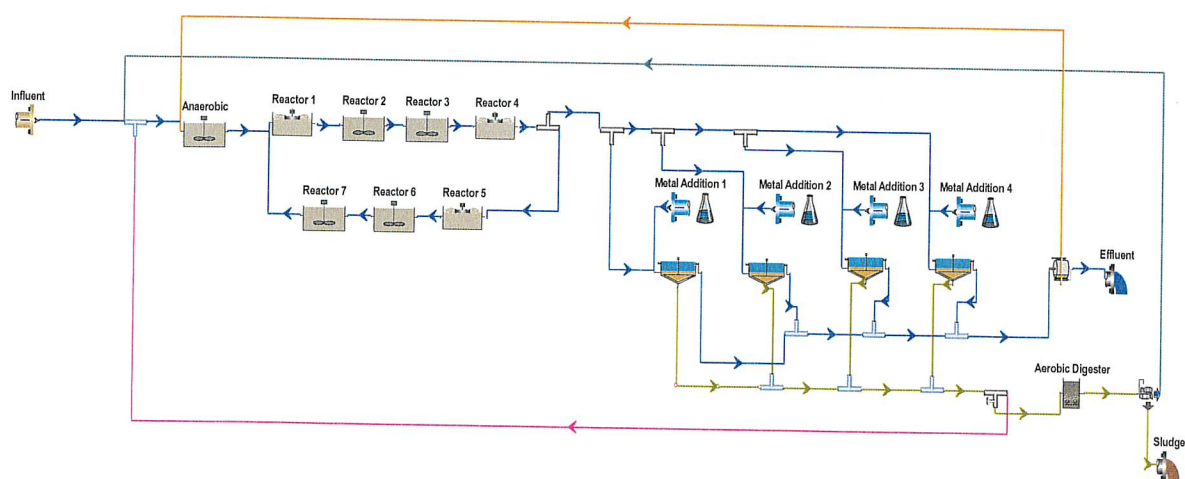
TP Removal Process Models

Biological phosphorus removal treatment consists of a set of continuous flow zones or basins that are mixed to provide an ideal environment for bacteria that specifically target phosphorus compounds. An anaerobic basin, where influent wastewater and return activated sludge (RAS) are mixed, is necessary prior to each of LEF WWTP's oxidation ditches to biologically remove phosphorus. New rectangular concrete tanks located on the influent end of each oxidation ditch were examined to provide this required anaerobic volume, per the following flow schematic, where they are shown as the *anaerobic* icon (two tanks represented as a combined volume in the model). RAS and influent wastewater would be combined and distributed in the existing flow splitter box and operated in the same fashion as currently performed.



Anaerobic volumes providing hydraulic residence time (HRT) of at least 1.5 hours for current influent flow rates were examined for TP removal capabilities. Modeled anaerobic volumes ranged from 0.88 MG to 2.0 MG, and were shown to remove nominally 0.5 mg/L of TP for winter and summer current conditions. Both models were configured for LEF WWTP operating at a 7-day solids retention time (SRT). As influent flows increased towards the maximum day influent flow of 21.0 mgd, projected TP effluent concentrations ranged from 1.6 mg/L to 1.4 mg/L (0.88 MG and 2.0 MG anaerobic volumes respectively, and under winter conditions). Corresponding HRTs ranged from 0.7 hr to 1.6 hr.

With biological modeling indicating final effluent TP concentrations averaging 2.8 mg/L to 1.6 mg/L for current maximum day inflows, chemical coagulant addition will be necessary to meet the 1.0 mg/L TP effluent requirement. Chemical coagulant addition is modeled as metal addition in the BioWin model. Metal addition was modeled prior to each secondary clarifiers (as from a number of preliminary runs for the MEF WWTP analysis, the addition location had no impact on metal compound quantity or projected TP concentration in the final effluent). The optimal total metal dose was based on addition prior to the each secondary clarifier proportional to the flow apportioned to each. The metals addition model is shown in the following schematic.



BioWin models only have provisions for using iron-based coagulants, so the metal addition requirement projected by the LEF model was converted from iron addition to 48.6-percent aluminum sulfate solution

(which is commonly called *alum*). Use of alum is necessary at LEF WWTP because UV disinfection light sleeves are susceptible to ferrous-based fouling.

The model indicated that a metals addition of 290 gallons per day (gpd) of iron reduced the final effluent to 0.5 mg/L TP for both average day winter and summer flow conditions. B&N modeled to a 0.5 mg/L TP effluent content, as a 2.0 safety factor can account for slug phosphorus loads resulting from digester decanting or dewatering operations, or elevated influent loads.

Converting from iron to alum addition, it's projected a maximum of 270 gpd of alum would be necessary to produce 0.5 mg/L TP effluent target. Should the other four forms of aluminum-based coagulants be used, each contains more aluminum per gallon than alum and the overall daily volume necessary to be added would be less.

A final set of BioWin models were compiled to determine the impact of influent load upon optimal biological TP removal. By increasing the 2016-17 influent CBOD concentration and corresponding VSS content (under current flow conditions with all other parameters constant), carbon was available to fuel the phosphorus-reducing bacteria to produce a final effluent below 1.0 mg/L TP (and without any alum addition). For instance, if influent CBOD and VSS were increased by 100 mg/L and 50 mg/L respectively, TP in the final effluent is projected to be 0.10 mg/L in summer and 0.84 mg/L in winter.

WWTP Layout Modifications

The recommended facilities to allow LEF WWTP to consistently produce a TP effluent of 1.0 mg/L include constructing anaerobic basins integral with the existing oxidation ditches, and adding an alum storage and metering pump building. Those facilities, along with recommended modifications to existing related facilities are described in the list below.

- **Anaerobic Tanks:** Each rectangular concrete tanks preceding each oxidation ditch will be partitioned along their center with a fiberglass baffle wall, separating each tank into two equal zones. Each zone will be mixed with a submersible mixer. Flow between the ditches will be continued to be split at the splitter box, along with RAS being intermixed with the influent flow.
- **Chemical Addition System:** Bulk tanks and metering pumps housed in a metal building with concrete foundation will be provided. New PVC piping with injection points prior to the primary settling tanks and secondary clarifiers (into the splitter box for each) will be installed.
- **Process Stability Upgrades:** These modifications are recommended to manage influent wastewater, RAS, and waste activate sludge flows; along with optimizing oxidation ditch influent splitter box operation and conditioning mixed liquor influent into Clarifiers 1 and 2 (per the listing in the cost scope listed below).

As part of the electrical and instrumentation modifications necessary to support the existing and new facilities, an online phosphorus concentration monitoring system will be included to optimize the TP removal system.

WWTP Phosphorus Removal Cost Estimate

An order-of-magnitude cost estimate for the biological and chemical phosphorus removal facilities, coupled with the existing pump and process improvements was developed for the LEF WWTP. Detailed estimates for each option are attached to this TM. These costs are presented in 2017 dollars, and will require updating once the timeframe of the project is determined and the final scope refined, including;

- Installing rectangular concrete anaerobic basins integral with the head end of each oxidation ditch
- Modifying oxidation ditch influent piping and adding anaerobic basin drains
- Installing alum storage and metering pump building
- Adding VFDs to existing influent pumps
- Retrofitting influent splitter box with weir baffles, drain line, and relocated WAS pump
- Installing new mixed liquor grinder into existing Clarifier 1 and 2 splitter box
- Reducing RAS wetwell volume for each of the four existing wetwells
- Providing associated electrical and instrumentation upgrades, including phosphorus concentration monitoring system

The construction cost estimate is \$2,600,000 for the LEF WWTP conversion, with an accuracy range of plus 30-percent and minus 15-percent, for the probable scope of the project.

Cost Estimate Attachments

**Lower East Fork WWTP
Clermont County Ohio**

**Budget Level Cost Estimate
Chemical (Alum) Addition Phosphorus Removal Facility**

Item	Installed Cost
New Chemical Addition System	
Bulk FRP Tanks (4 @ 3000 gal) and Day Tank (500 gal)	\$ 50,000
Metal Building (2,000 sf)	\$ 116,000
Building Slab and Containment Concrete (80 cy)	\$ 80,000
Building HVAC and Plumbing	\$ 30,000
Metering Pumps (2 @ 20 gph, 6 @ 10 gph) on Four Skids	\$ 48,000
1" PVC Piping and Diffusers (480 lf)	\$ 14,000
2" PVC Piping and Diffusers (80 lf)	\$ 8,000
New Support Systems	
Electrical Modifications	\$ 76,000
Instrumentation Modifications	\$ 50,000
Electrical Room/Building Expansions for VFDs/MCCs (350 sf w/AC)	\$ 55,000
New Supplemental Process Improvements	
Influent Pump VFDs (1 @ 25HP, 4 @ 40HP, 2 @ 75HP)	\$ 53,000
RAS Wetwell Volume Reduction (4)	\$ 32,000
Influent Splitter Box Drain Line (6" @ 150 ft and Plug Valve)	\$ 13,000
Influent Splitter Box Baffle Plate	\$ 10,000
WAS Pump Relocation in Splitter Box	\$ 12,000
Online Phosphorus Concentration System Monitor	\$ 26,000
Mixed Liquor Grinder in Clarifier 1/2 Splitter Channel	\$ 110,000
Subtotal	\$ 783,000
Contingency (24%)	\$ 188,000
Bond/Mobilization/Insurance/O&P (18%)	\$ 141,000
Budget Level Construction Cost Total (2017 Dollars, Rounded)	\$ 1,100,000

**Lower East Fork WWTP
Clermont County Ohio**

**Budget Level Cost Estimate
Biological-Chemical Components for Phosphorus Removal Facility**

Item	Installed Cost
New Anaerobic Tanks	
Concrete Tanks (Slab and Walls, 700 cy)	\$ 840,000
Demolition (Piping-Road-Concrete)	\$ 18,000
Fixed Weir	\$ 12,000
Submersible Mixers (4)	\$ 100,000
Drain Piping and Valves	\$ 25,000
Walkways, Stairs, and Mixer Access Platforms	\$ 40,000
New Chemical Addition System	
Bulk FRP Tanks (2 @ 3000 gal) and Day Tank (200 gal)	\$ 22,000
Metal Building (620 sf)	\$ 35,000
Building Slab and Containment Concrete (44 cy)	\$ 44,000
Building HVAC and Plumbing	\$ 24,000
Metering Pumps (2 @ 10 gph, 6 @ 5 gph) on Four Skids	\$ 34,000
1" PVC Piping and Diffusers (480 lf)	\$ 14,000
2" PVC Piping and Diffusers (80 lf)	\$ 8,000
New Support Systems	
Electrical Modifications	\$ 230,000
Instrumentation Modifications	\$ 60,000
Electrical Room/Building Expansions for VFDs/MCCs (350 sf w/AC)	\$ 55,000
New Supplemental Process Improvements	
Influent Pump VFDs (1 @ 25HP, 4 @ 40HP, 2 @ 75HP)	\$ 53,000
RAS Wetwell Volume Reduction (4)	\$ 32,000
Influent Splitter Box Drain Line (6" @ 150 ft and Plug Valve)	\$ 13,000
Influent Splitter Box Baffle Plate	\$ 10,000
WAS Pump Relocation in Splitter Box	\$ 12,000
Online Phosphorus Concentration System Monitor	\$ 26,000
Mixed Liquor Grinder in Clarifier 1/2 Splitter Channel	\$ 110,000
Subtotal	\$ 1,817,000
Contingency (24%)	\$ 436,000
Bond/Mobilization/Insurance/O&P (18%)	\$ 327,000
Budget Level Construction Cost Total (2017 Dollars, Rounded)	\$ 2,600,000